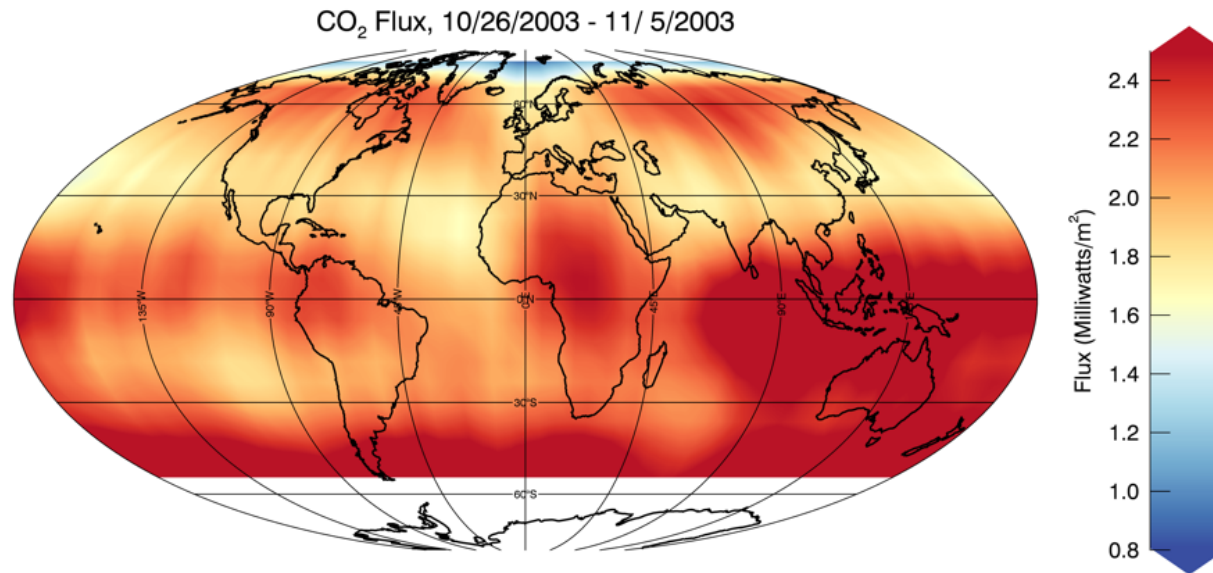


Energetics of the Thermosphere in Polar Regions Observed by SABER



Martin G. Mlynczak, *NASA Langley Research Center*

Linda A. Hunt, *SSAI*

&

The SABER Science Team

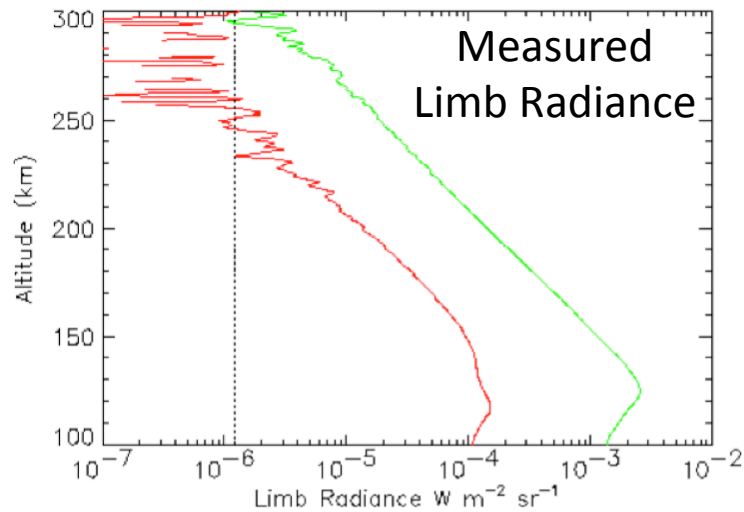
Outline

- **Acknowledgement**
- **Derivation of infrared cooling parameters from SABER measurements**
- **Current state of the thermosphere**
- **Results – by latitude section (global – equatorial - polar)**
- **Top 6 storms over past 14 years**
- **Summary**

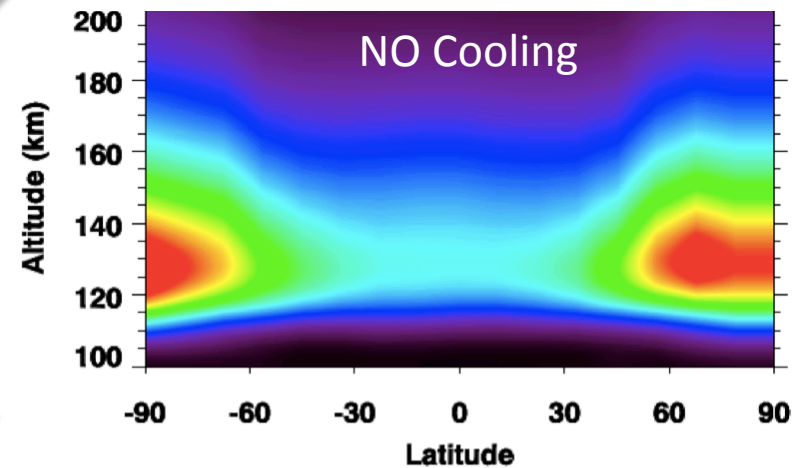
Acknowledgement

- Today we will look at data from the NASA TIMED satellite and the SABER instrument that was launched 14 years ago on 7 December 2001.
- This talk is possible only because in the late 1990's, numerous engineers, project managers, resource analysts, and technicians did an excellent job of building and testing the TIMED instruments and satellite
- This talk is dedicated to them, for the outstanding job they did, which provides all of us the privilege of doing science with the data

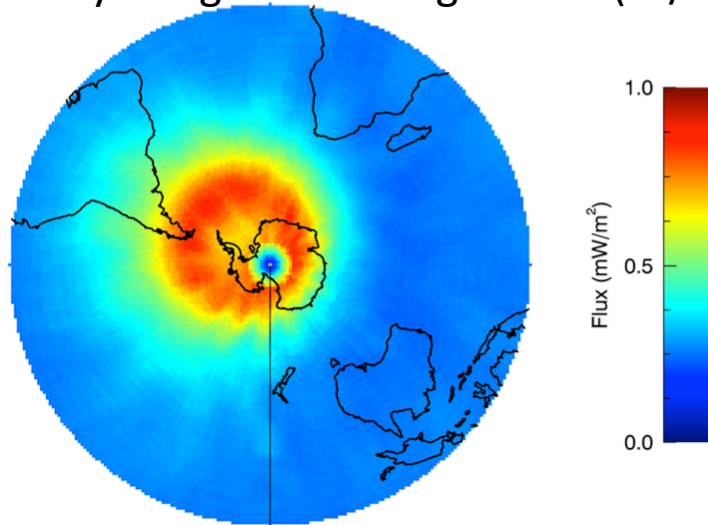
Infrared Cooling Parameters Derived by SABER



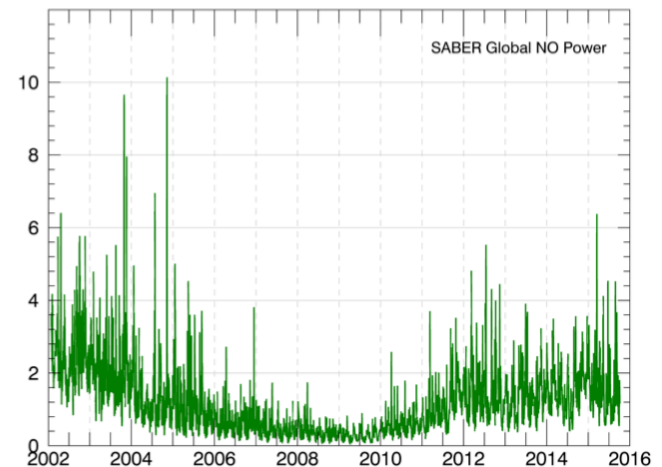
Abel Inversion to Cooling Rate (W/m^3)



Vertically Integrate Cooling to Flux (W/m^2)



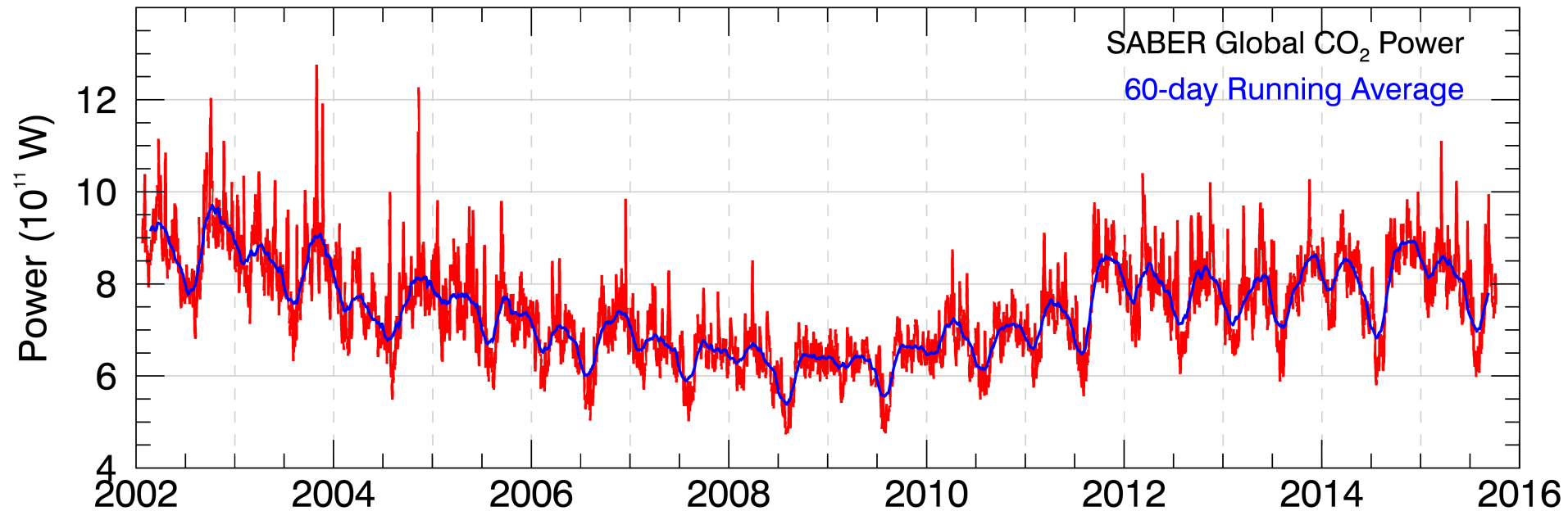
Area integrate to get global power (W)



Current State of the Thermosphere

SABER Global Power from CO₂

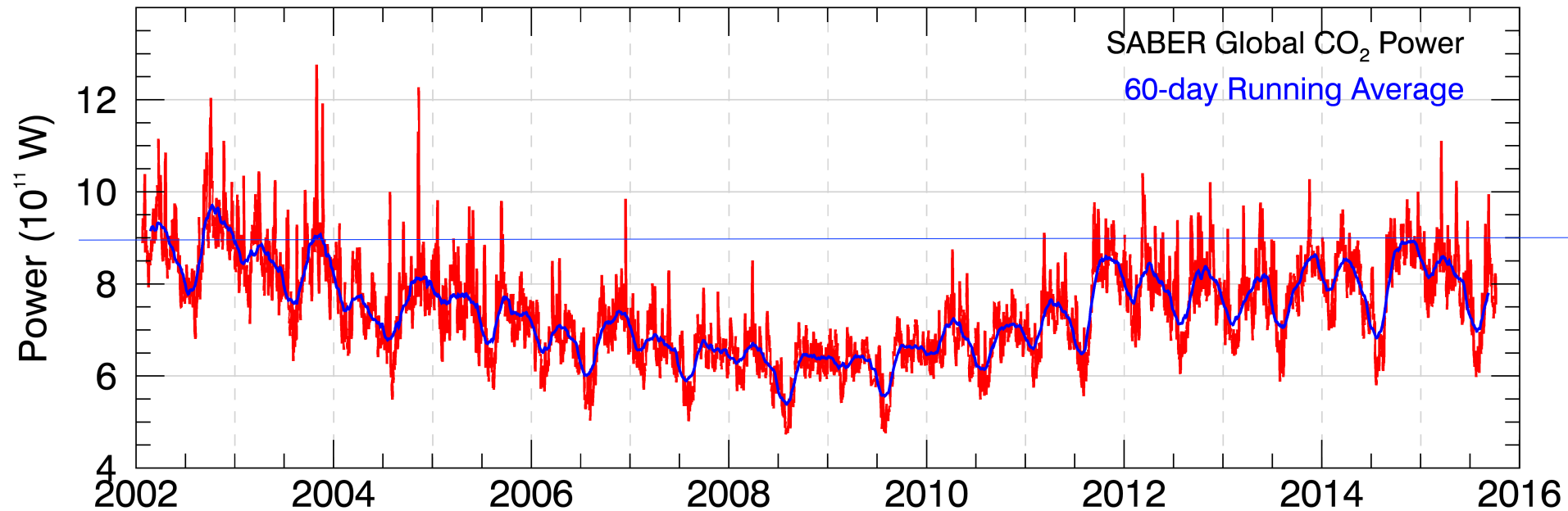
Jan 2002 – Dec 2015; 100 – 140 km



Over 5050 days of data now!
Strong semi-annual cycle evident in global cooling
Evidence of response to geomagnetic activity in each “spike”

SABER Global Power from CO₂

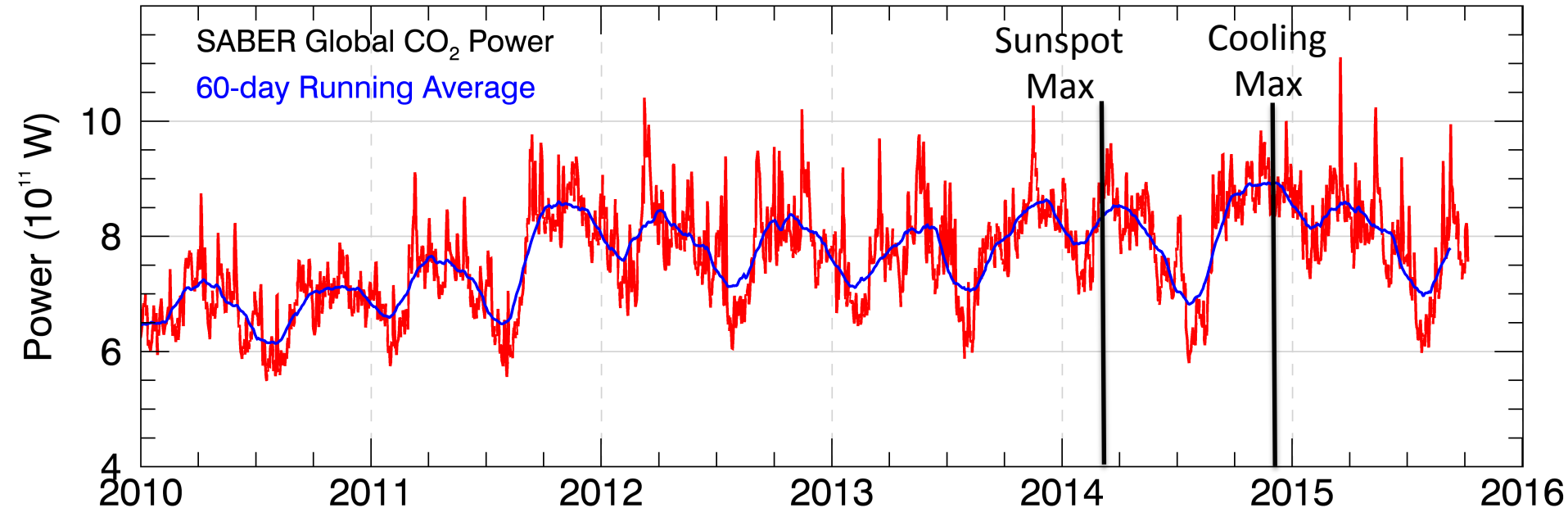
Jan 2002 – Dec 2015; 100 – 140 km



SC 24 solar max (12/2014) as warm as 12/2003 – 11 years
SC 24 clearly weaker than SC 23
Minimum cooling in 2008 coincident with semi-annual cycle

SABER Global Power from CO₂

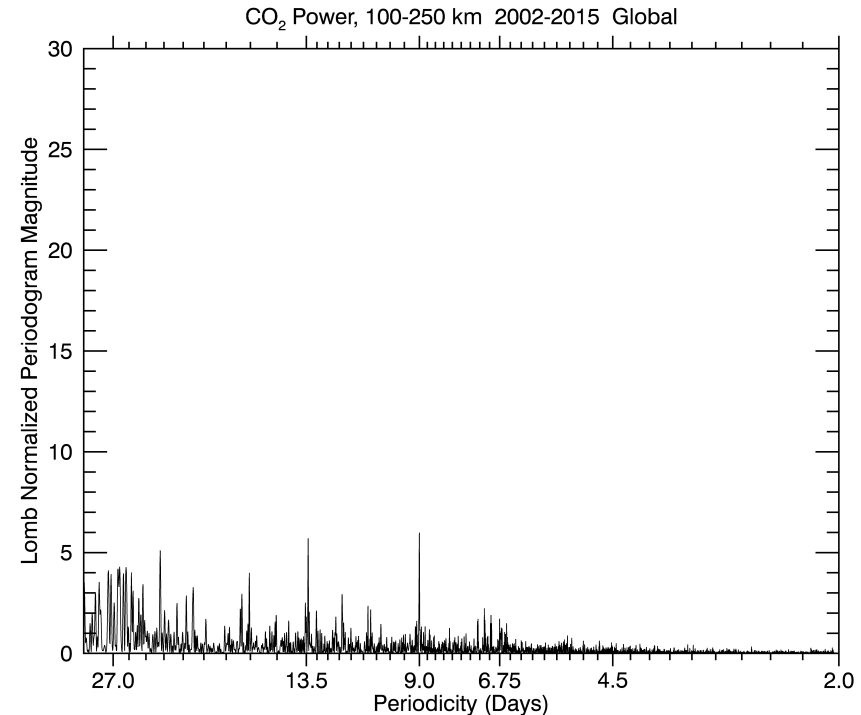
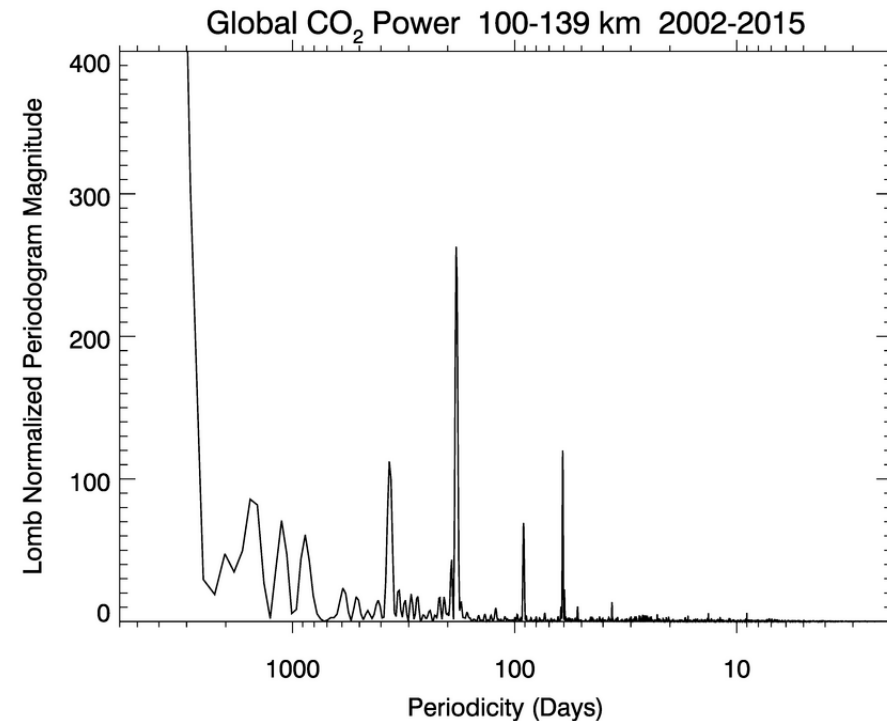
Jan 2010 – Dec 2015; 100 – 140 km



Sunspot Maximum Occurred in April 2014
CO₂ Cooling Maximum Occurred in 12/2014
Sunspot and Cooling Maxima not Coincident
We are now heading to solar minimum!

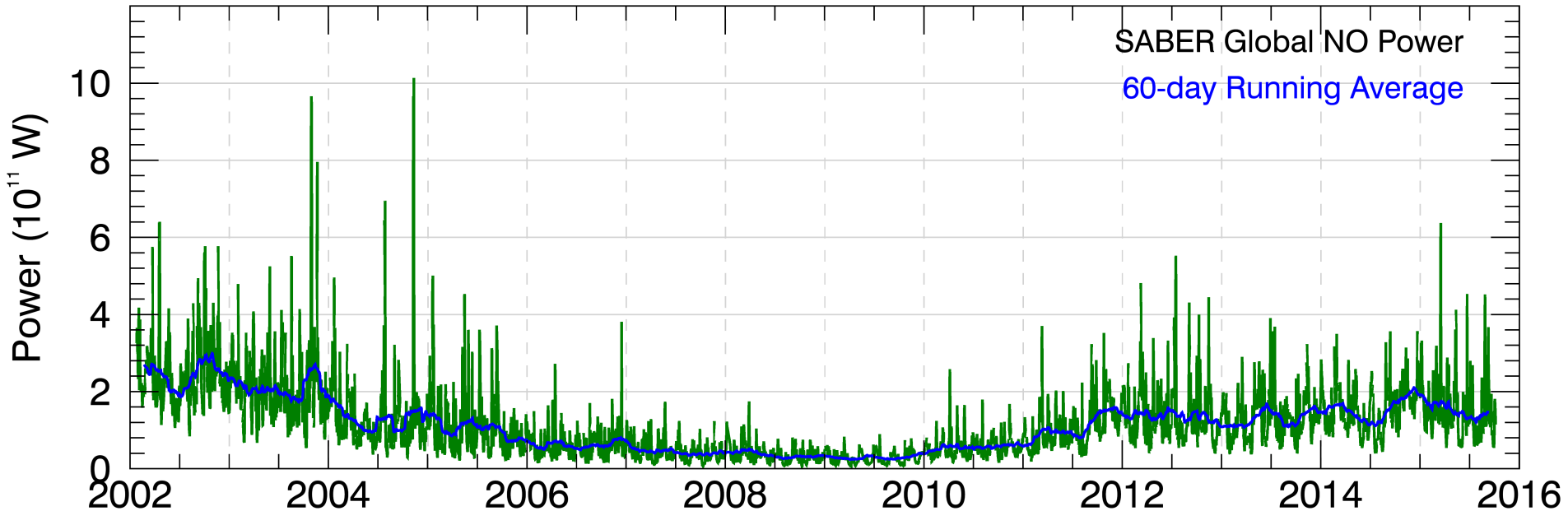
CO₂ Global Power 2002 - 2015

Lomb Normalized Periodogram



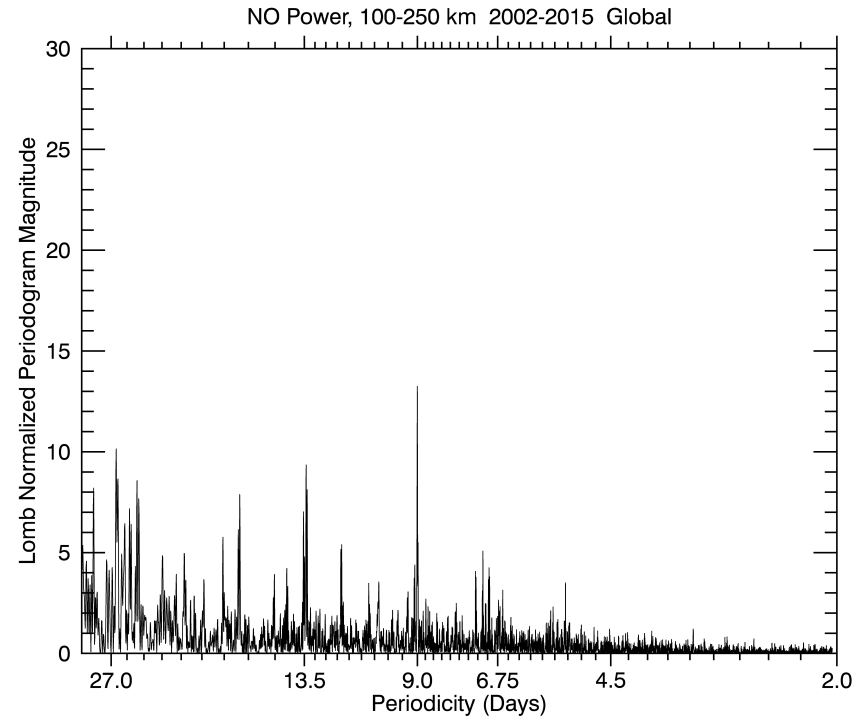
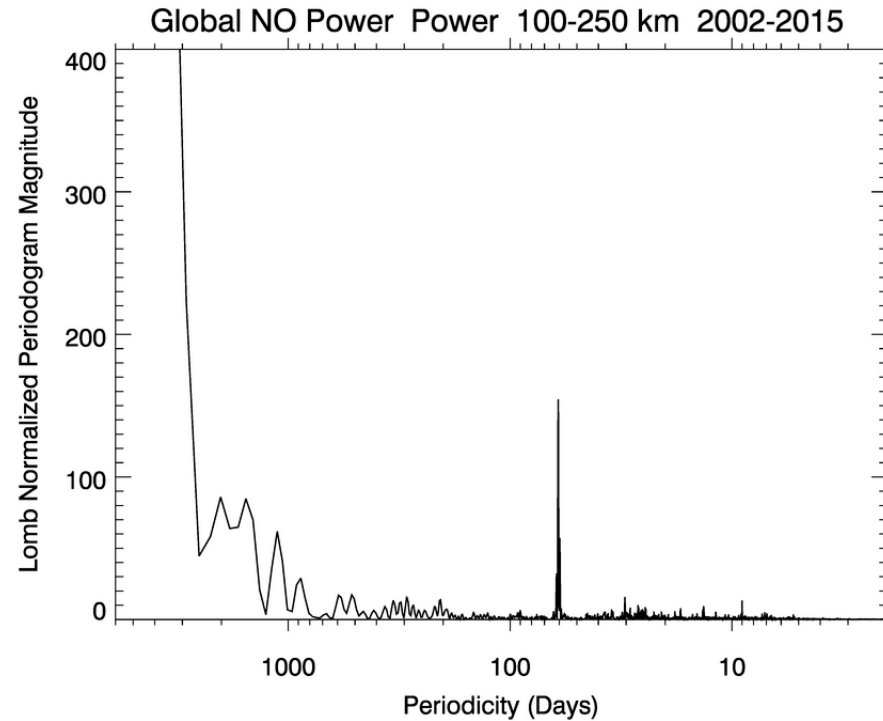
SABER Global Power From NO

Jan 2002 – Dec 2015: 100 – 250 km



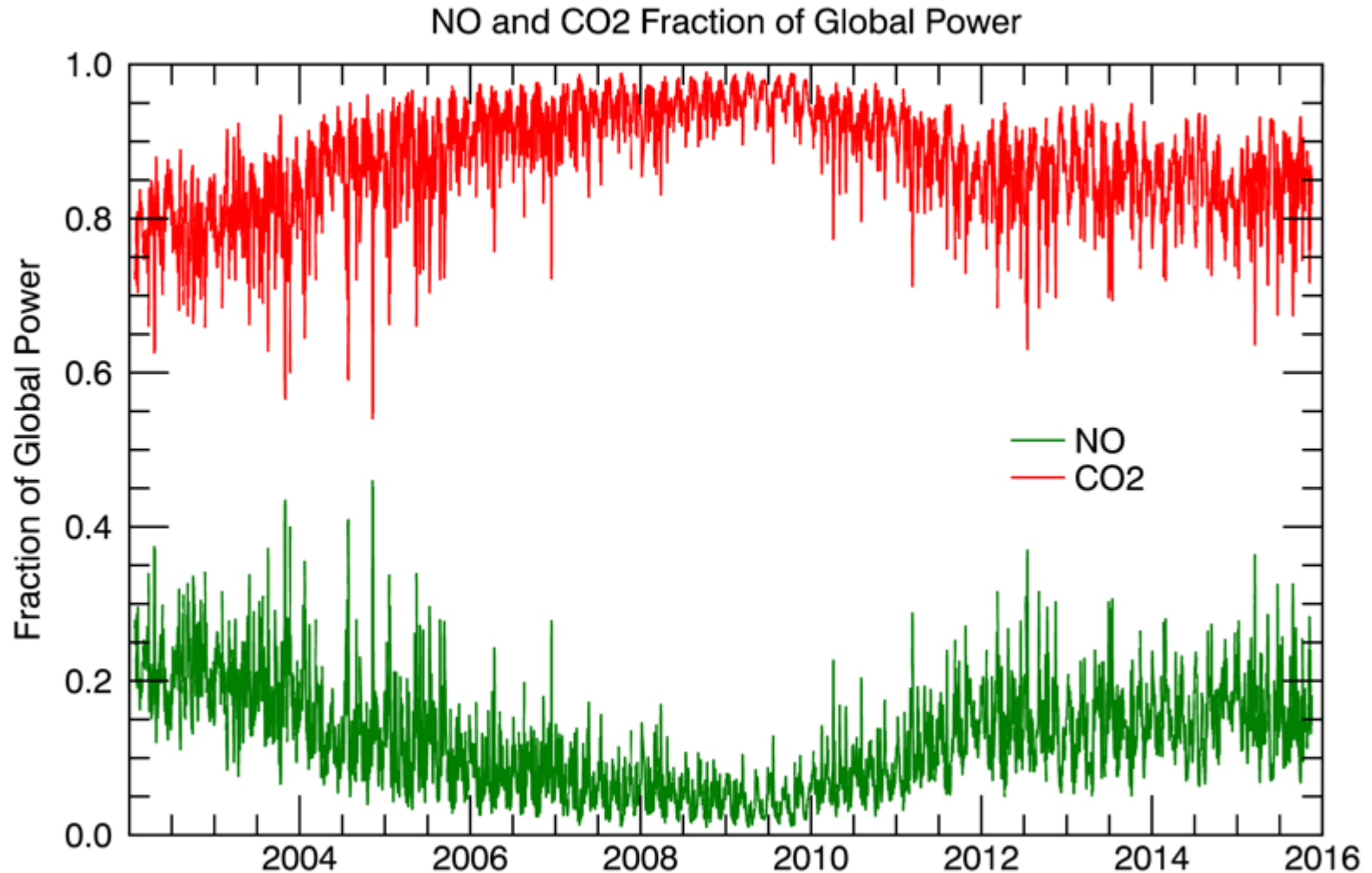
NO Global Power 2002 - 2015

Lomb Normalized Periodogram

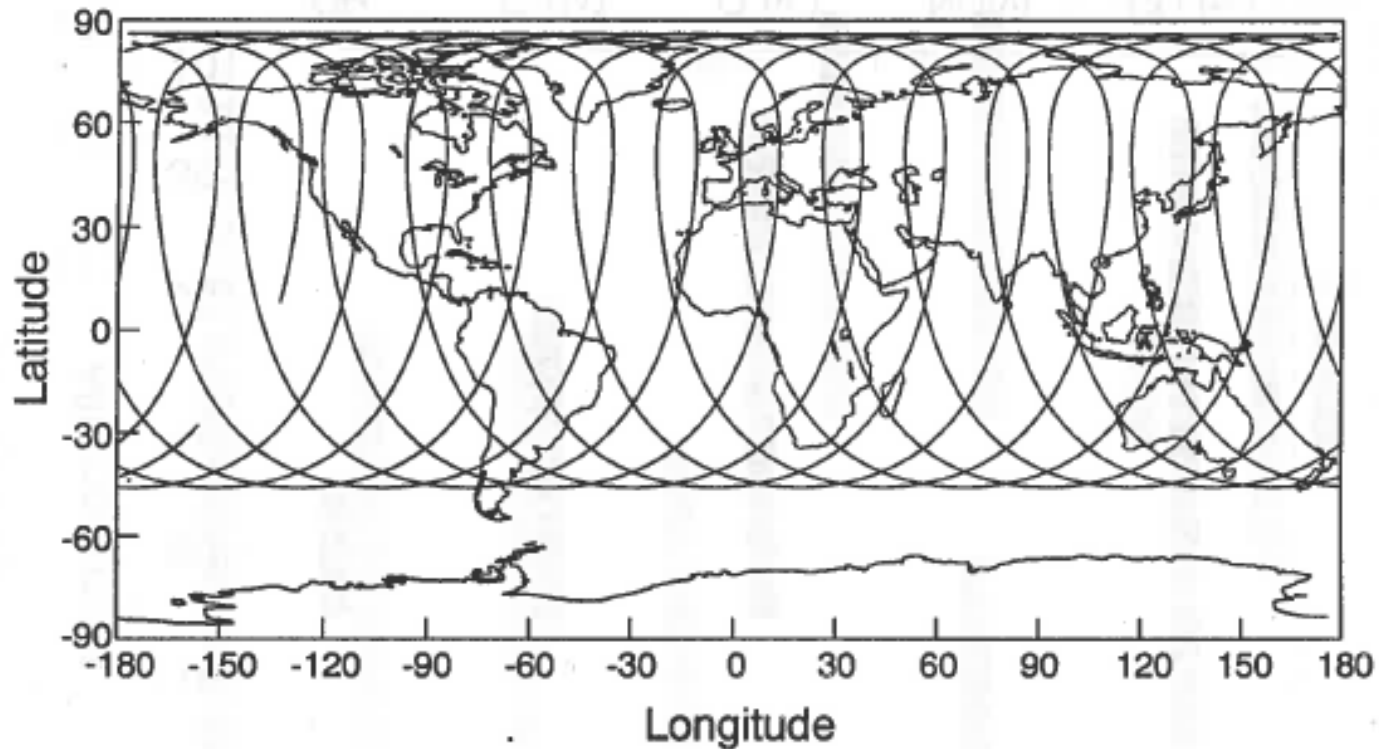


Fraction of Thermosphere Global Infrared Power

- CO₂ and NO -



Infrared power as a function of Latitude



SABER alternately samples poleward of ~ 55 Deg every 2 months

90% of atmospheric area observed at any one time

Hemispheric and Polar Infrared Power (GW)

Averages Over 14 Years of SABER Data

	Global (GW)	0 – 55 N	0 – 55 S	55 – 90 N	55 -90 S
Carbon Dioxide	744.2	307.6	301.5	68.4	66.7
Fraction of CO ₂ Cooling	-	41.3%	40.5%	9.2%	9.0%
Fraction of Atmospheric Area		41%	41%	9%	9%
Nitric Oxide	113.1	39.4	40.8	16.1	16.8
Fraction of NO Cooling	-	34.8%	36.1%	14.2%	14.9%
NO Fraction of Total	13%	11%	12%	19%	20%

Interim Summary

Long-Term Average Effects

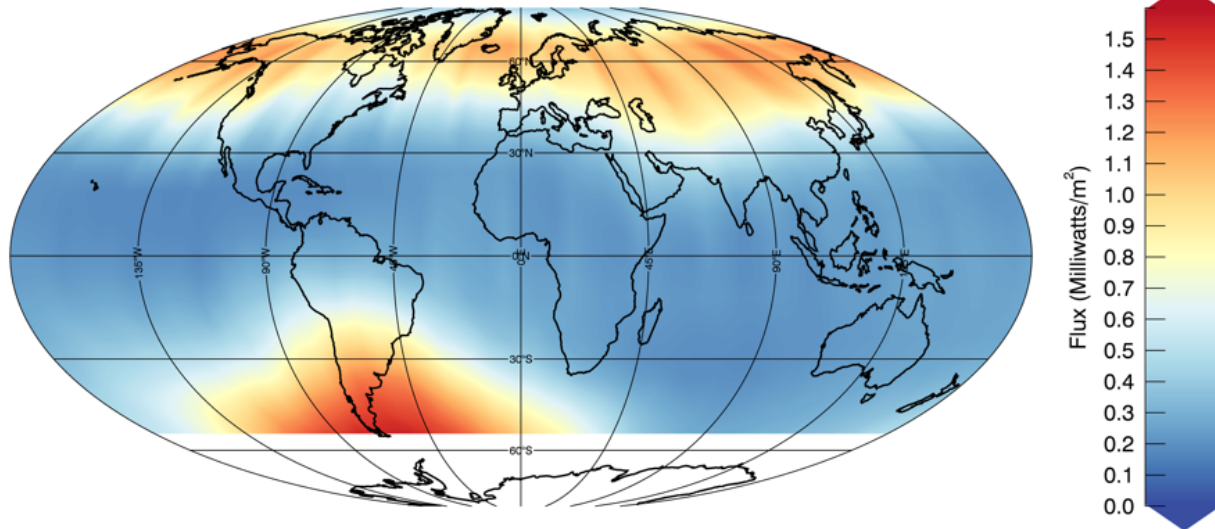
- Hemispheric asymmetry in cooling by NO or CO₂ is not observed – in the long term global mean
- CO₂ cooling is in direct proportion to atmospheric area
- NO emission comprises 20% of polar cooling
- NO emission is 11% of cooling between +/- 55°

Top 6 Strongest Storms

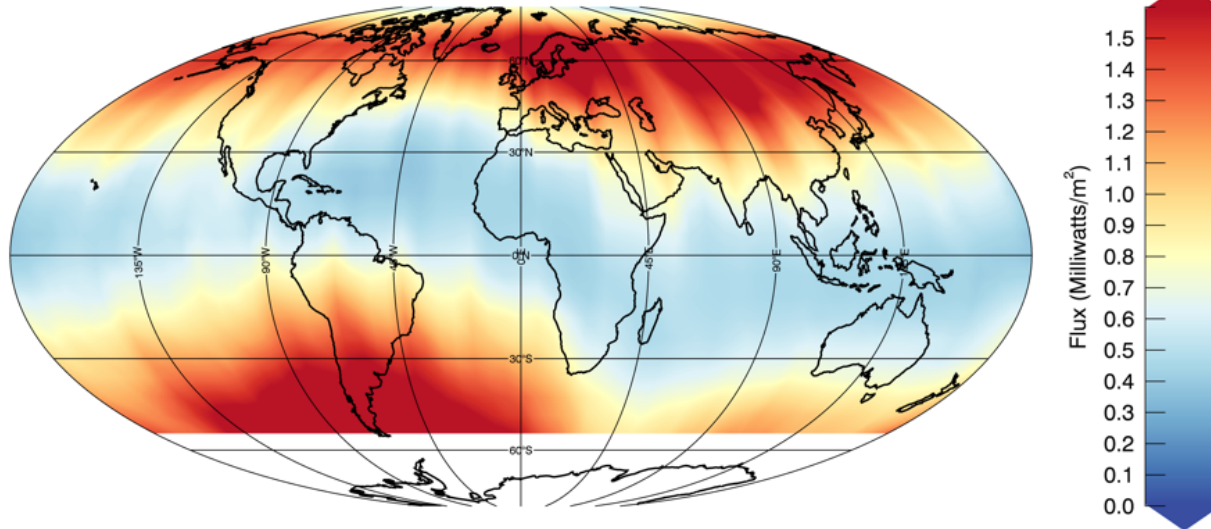
2002 – 2015

- **Definition: NO power $> 5e+11$ W for 2 or more days**
- **Only six such storms in 14 years**
- **Compare NO and CO₂ power**
 - **Globally; by Hemisphere; Polar regions**

NO Flux, 10/21/2003 - 10/25/2003



NO Flux, 10/26/2003 - 11/5/2003



NO Infrared Flux Before and During the Halloween Storms 2003

Top 6 Storms of the SABER Era, 2002 - Present

Year	Days	Global NO + CO ₂ Power (TeraWatts)	Name
2003	302-304	3.03	Halloween Storm
2004	313-315	2.88	Veteran's Day Storm
2004	207-209	2.35	Parent's Day Storm
2002	108-110	2.00	Paul Revere Day Storm
2002	274-277	1.53	Temperance Day Storm
2003	324-325	0.89	Television Day Storm

These storms were chosen as they are the only times when the NO power exceeded 5×10^{11} W for 2 or 3 days

Relative Roles of NO and CO₂ During Top 6 Storms

Year	Days	Percent Global Power NO	% Global Power CO2
2003	302-304	65	35
2004	313-315	68	32
2004	207-209	63	37
2002	108-110	70	30
2002	274-277	66	34
2003	324-325	53	47

**NO Emission Dominates the Thermostat Effect
During Intense Storm Conditions**

Hemispheric Power During Top 6 Storms - NO

Year	Days	Northern Hemisphere NO (10^{11} W)	Southern Hemisphere NO (10^{11} W)
2003	302-304	8.51	11.0
2004	313-315	8.55	11.4
2004	207-209	8.24	6.44
2002	108-110	7.99	5.89
2002	274-277	4.61	5.49
2003	324-325	1.85	2.81

4 of 6 storms exhibit strong bias to southern hemisphere for NO

Hemispheric Power During Top 6 Storms – CO₂

Year	Days	Northern Hemisphere CO ₂ (10 ¹¹ W)	Southern Hemisphere CO ₂ (10 ¹¹ W)
2003	302-304	5.11	5.56
2004	313-315	4.27	4.81
2004	207-209	4.20	4.61
2002	108-110	3.03	3.06
2002	274-277	1.83	3.38
2003	324-325	1.84	2.36

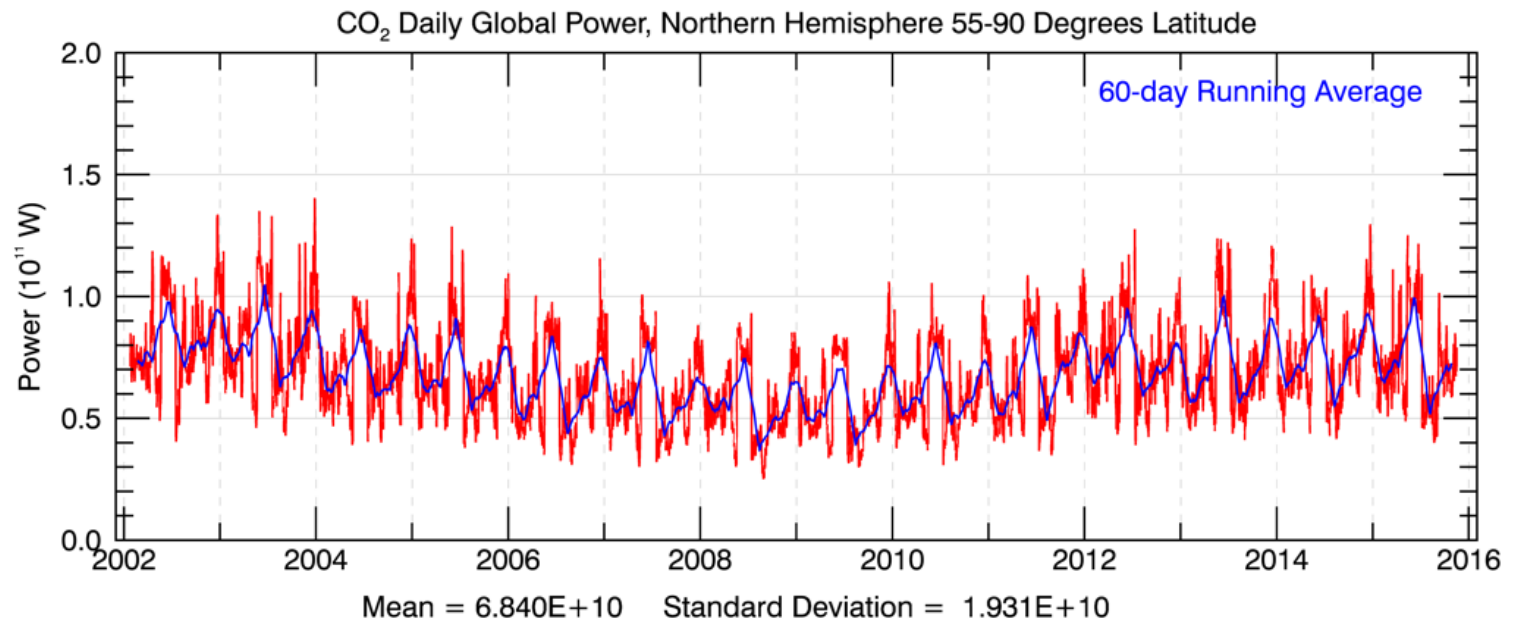
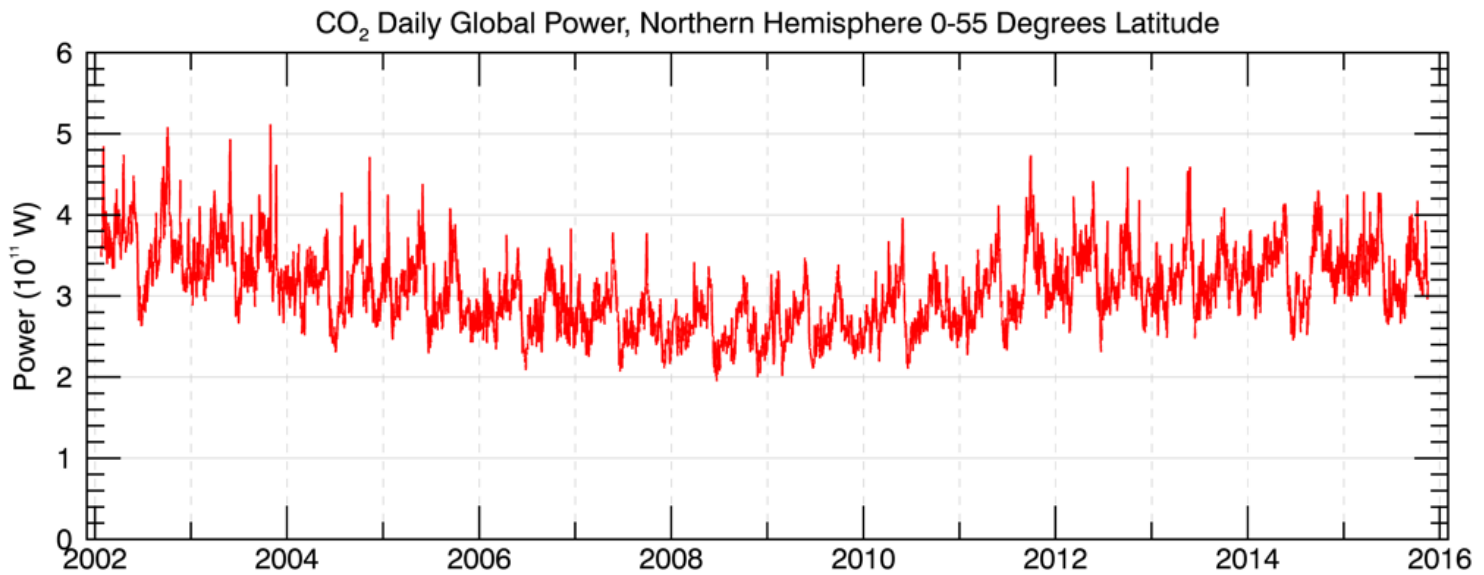
CO₂ power is greatest in southern hemisphere in all six storms

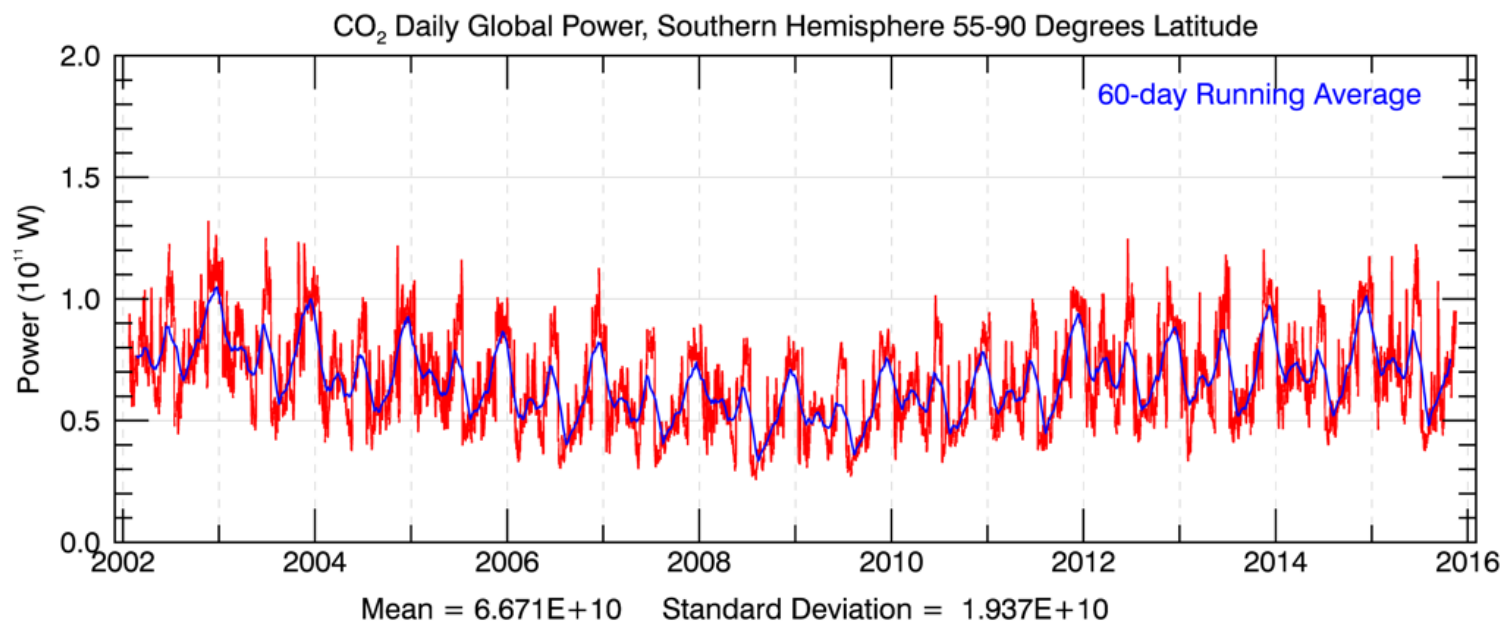
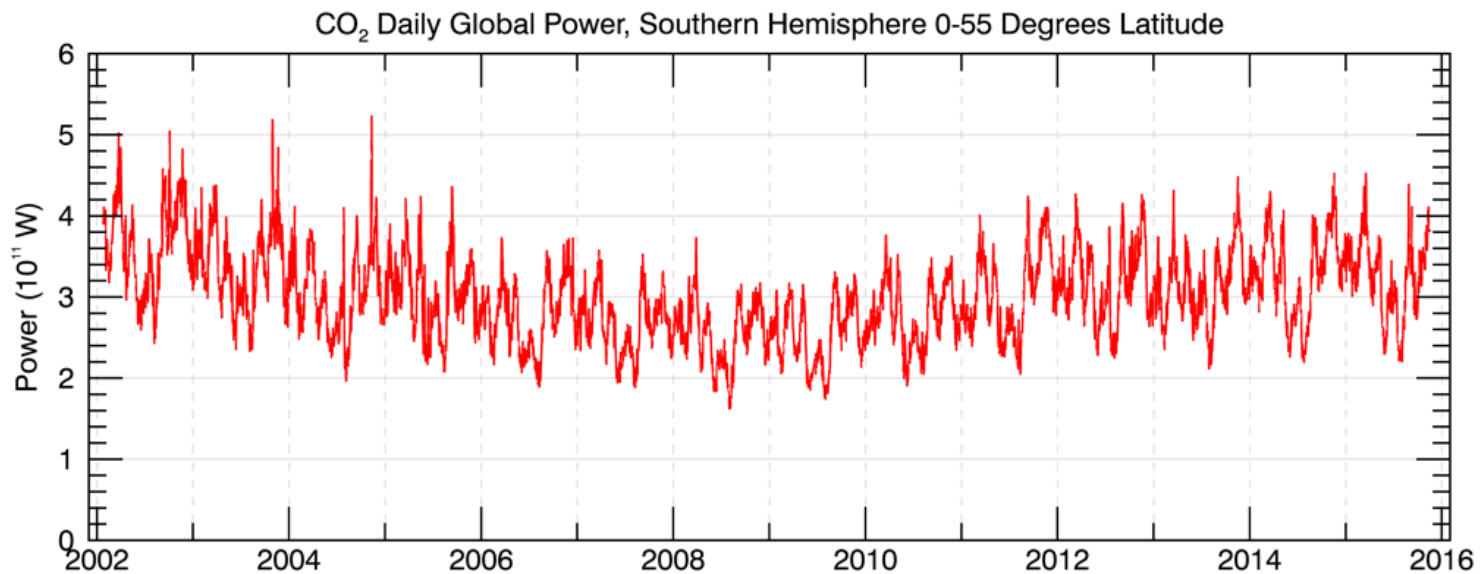
Overall strongest storms have have maximum IR emission in SH

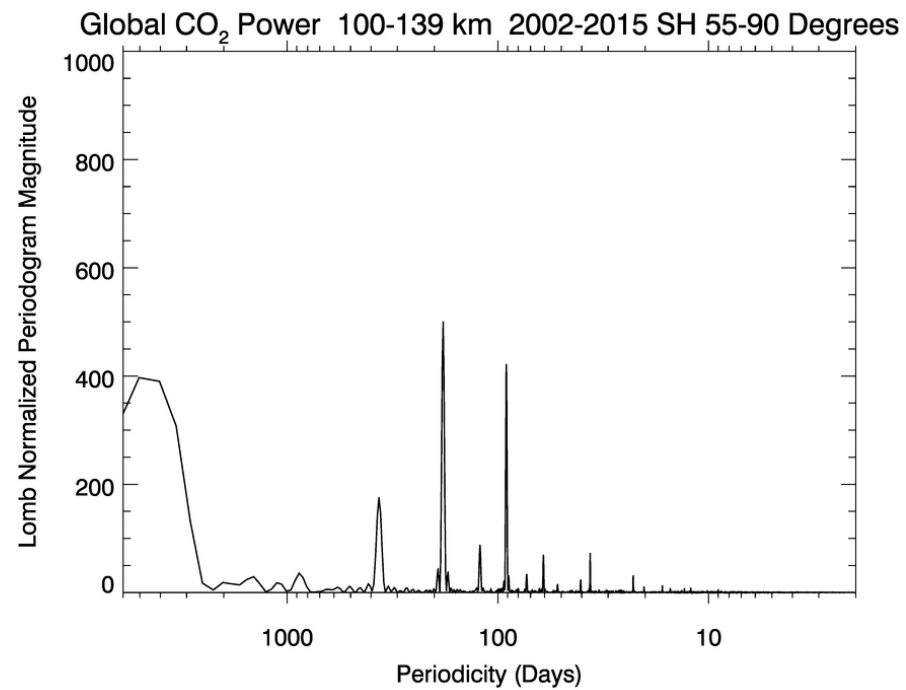
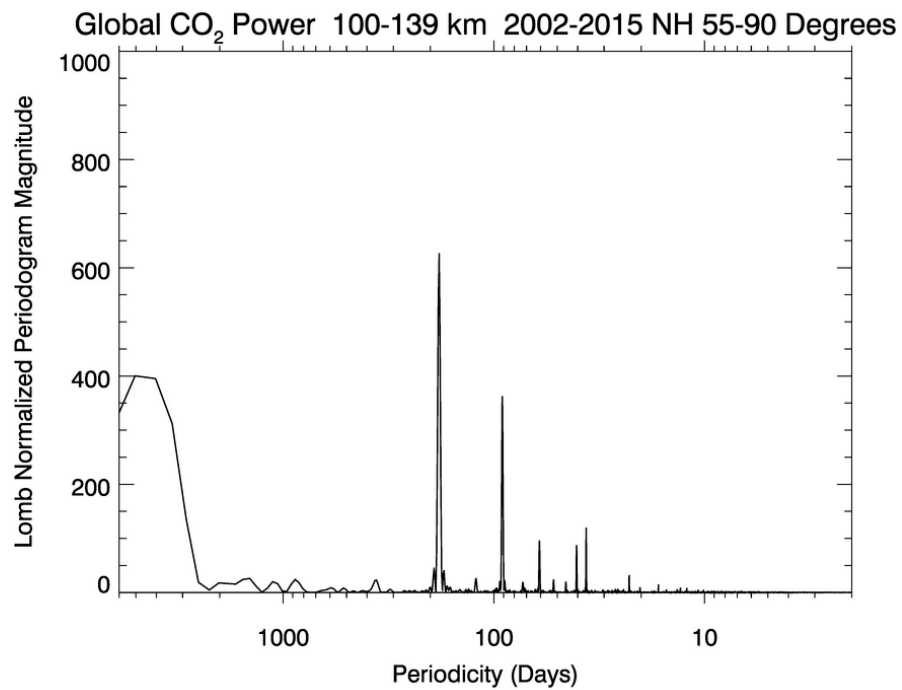
Summary And Conclusions

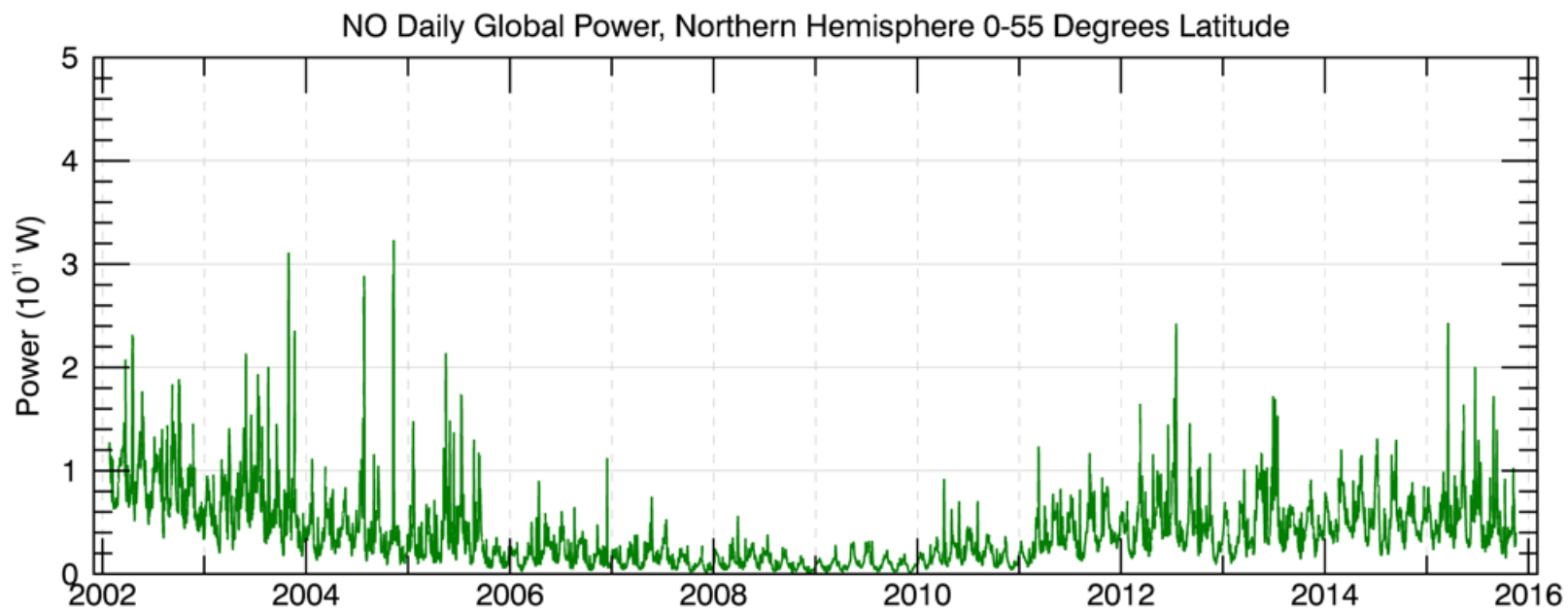
- Fourteen years of data allow us to examine short term (days) to long term variability of thermosphere IR cooling
- Clear evidence of solar/geomagnetic influence on cooling
- In the long term, CO₂ cooling is found to be uniform over the planet (CO₂ cooling/area ratio is constant)
- For storm conditions, NO emission is the dominant thermostat effect
- For the six strongest storms, there is a clear “asymmetry” or “bias” to the southern hemisphere – more IR cooling SH vs NH
- Now heading to solar minimum
 - Will there be strong storms in declining phase of SC 24 as in SC 23?
 - Will coronal holes return providing short term periodic features again?

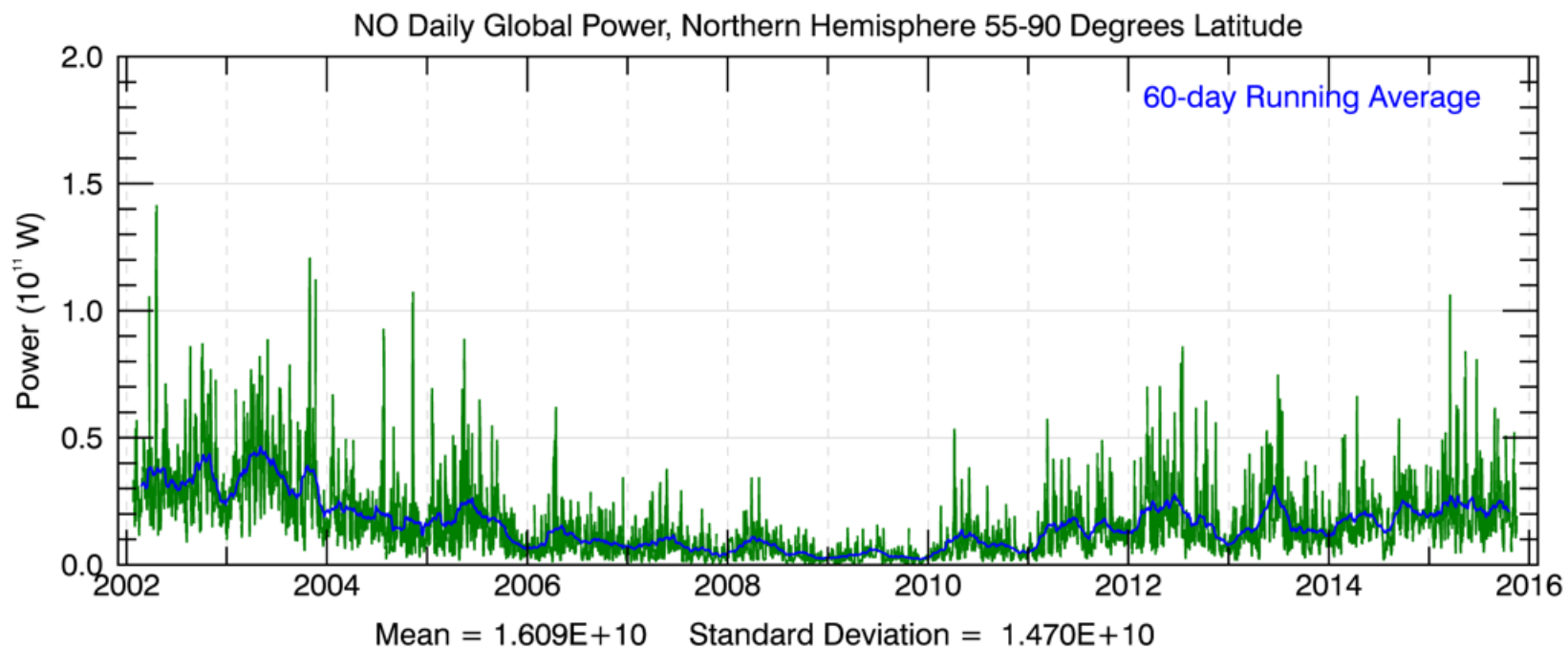
Backups

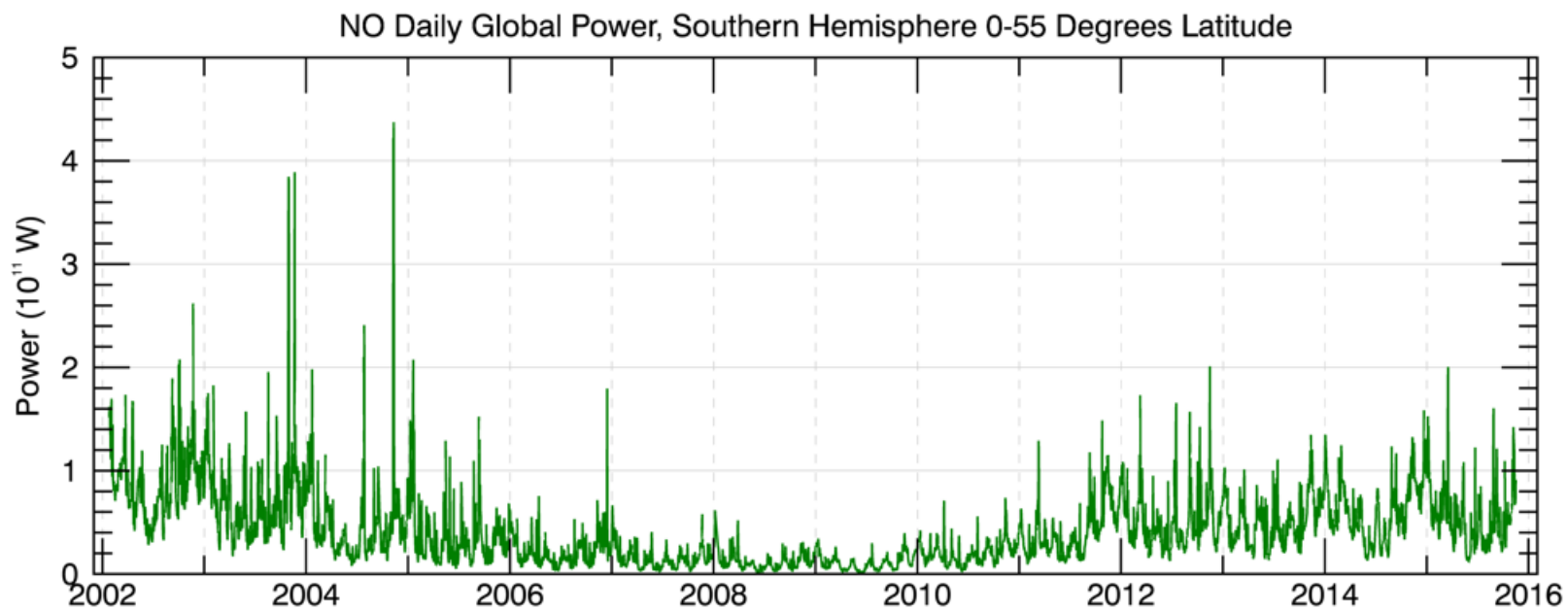


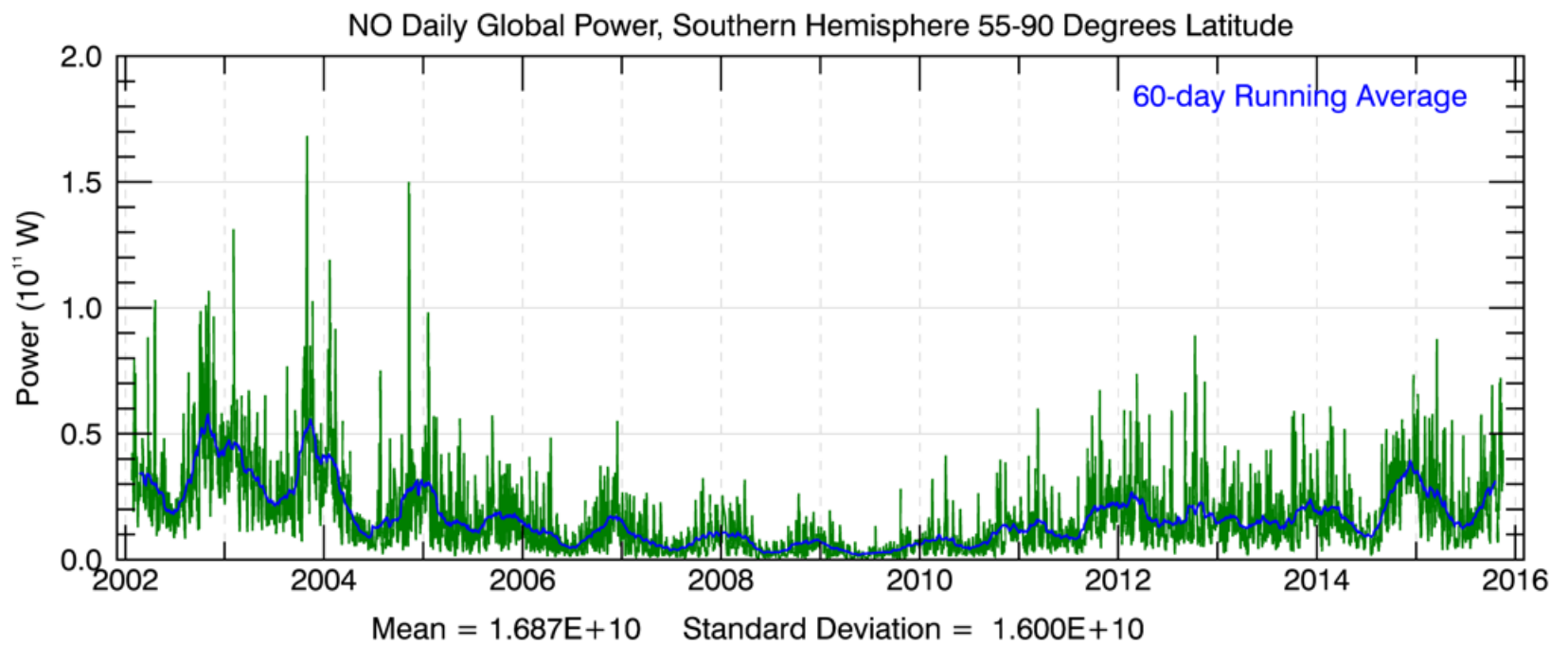




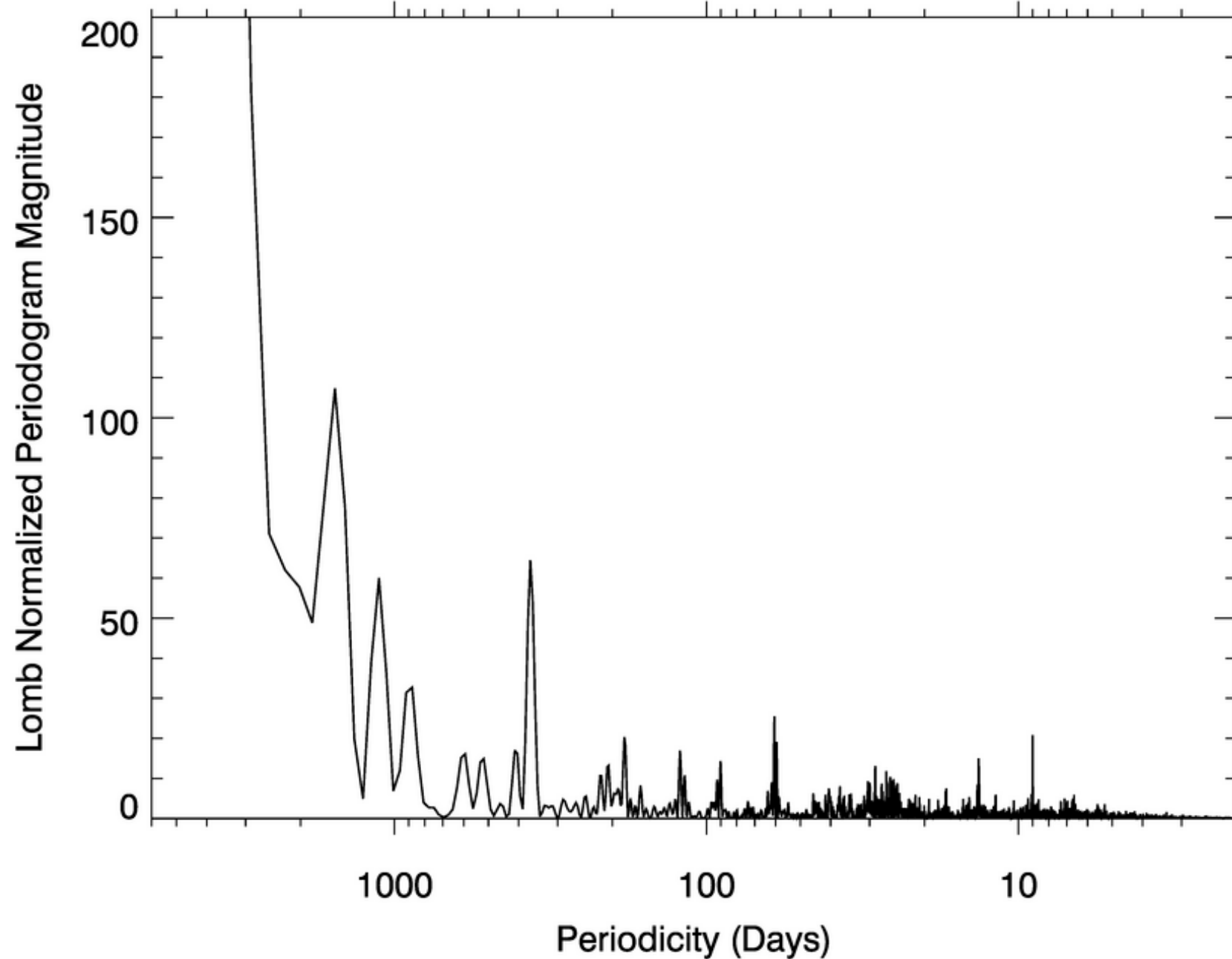




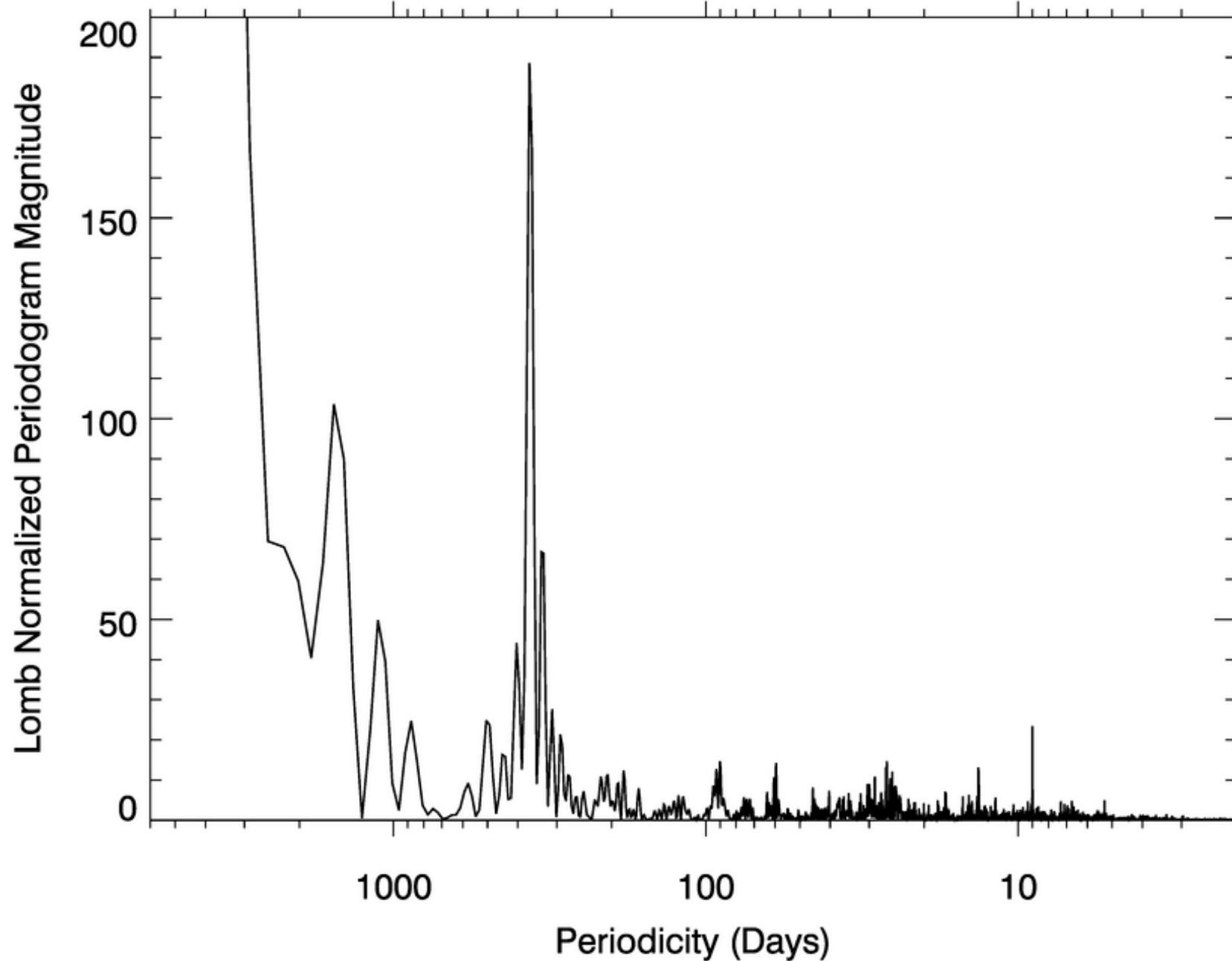


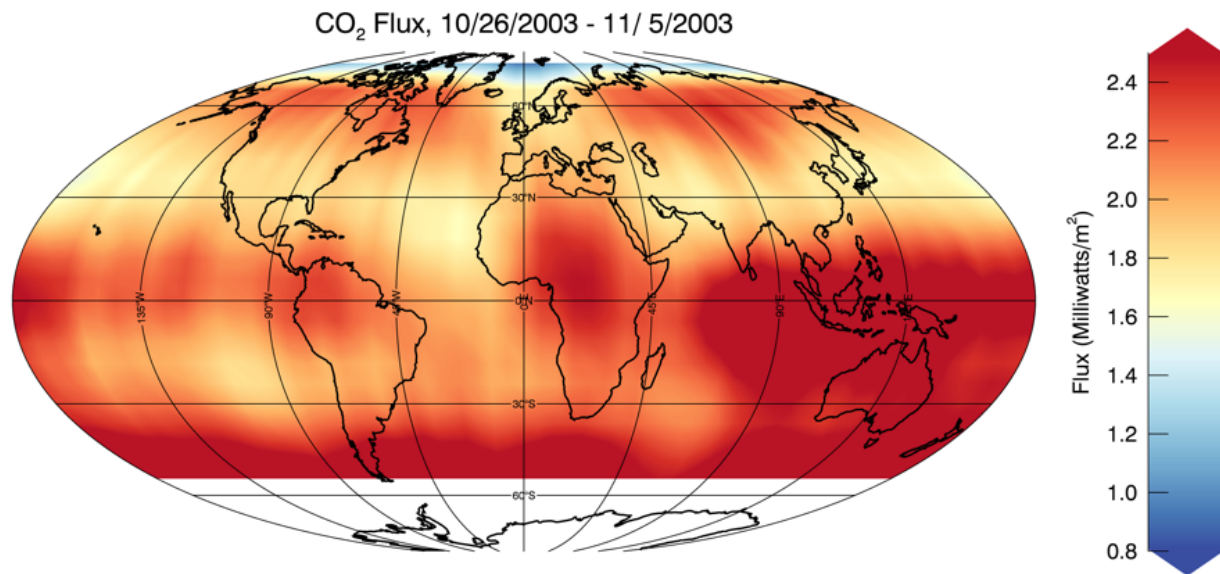


Global NO Power Power 100-250 km 2002-2015 NH 55-90 Degree

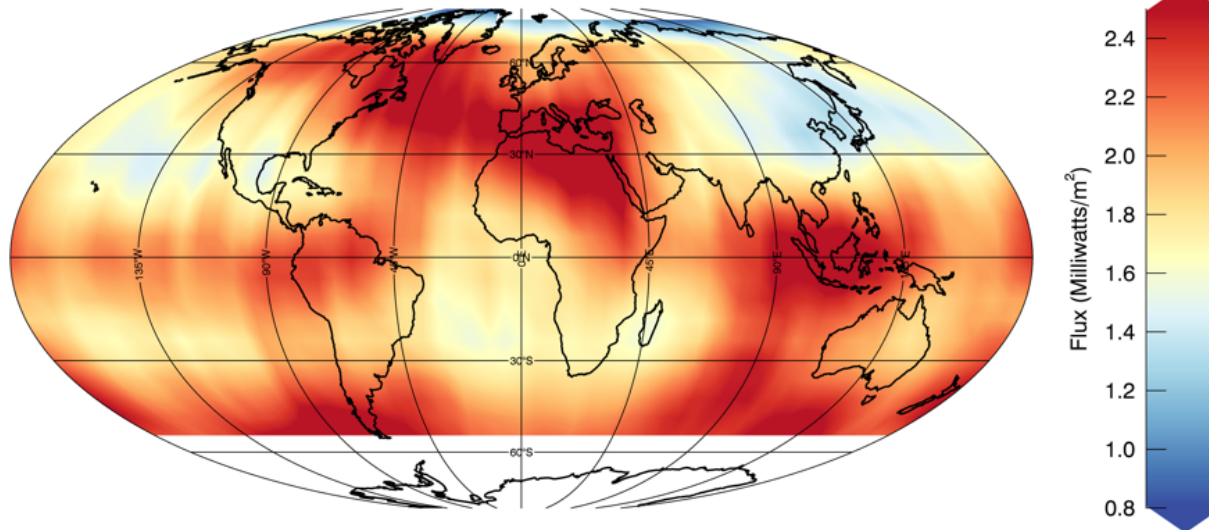


Global NO Power Power 100-250 km 2002-2015 SH 55-90 Degree

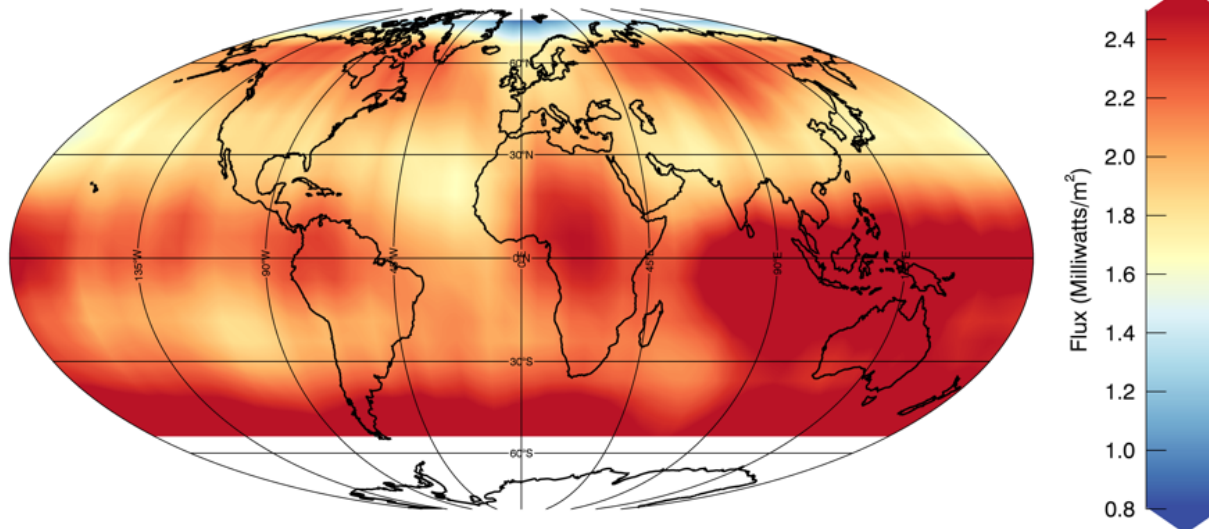




CO₂ Flux, 10/21/2003 - 10/25/2003

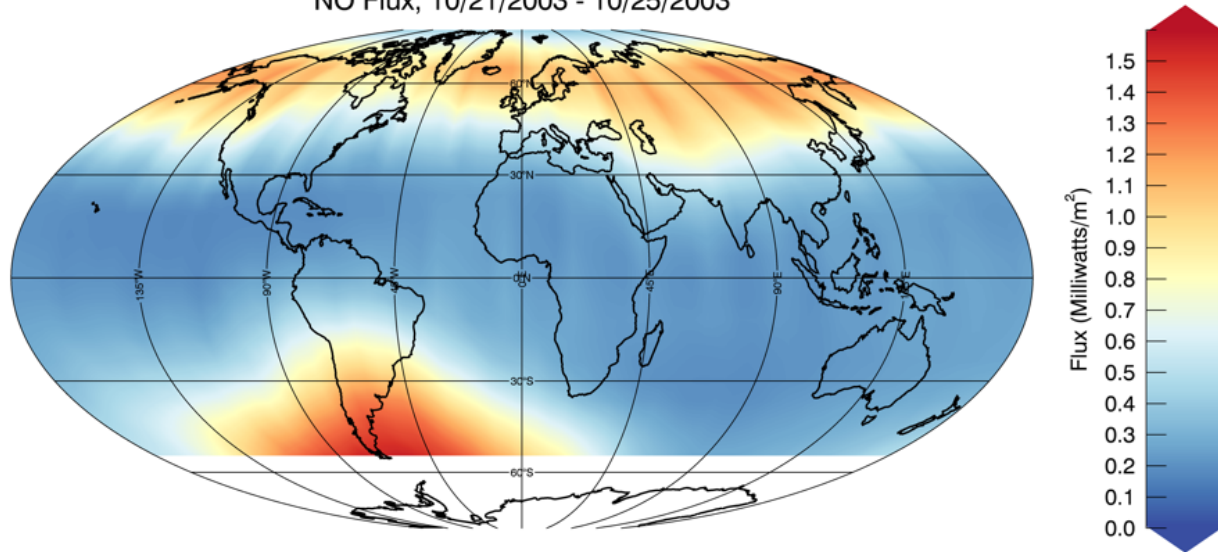


CO₂ Flux, 10/26/2003 - 11/5/2003

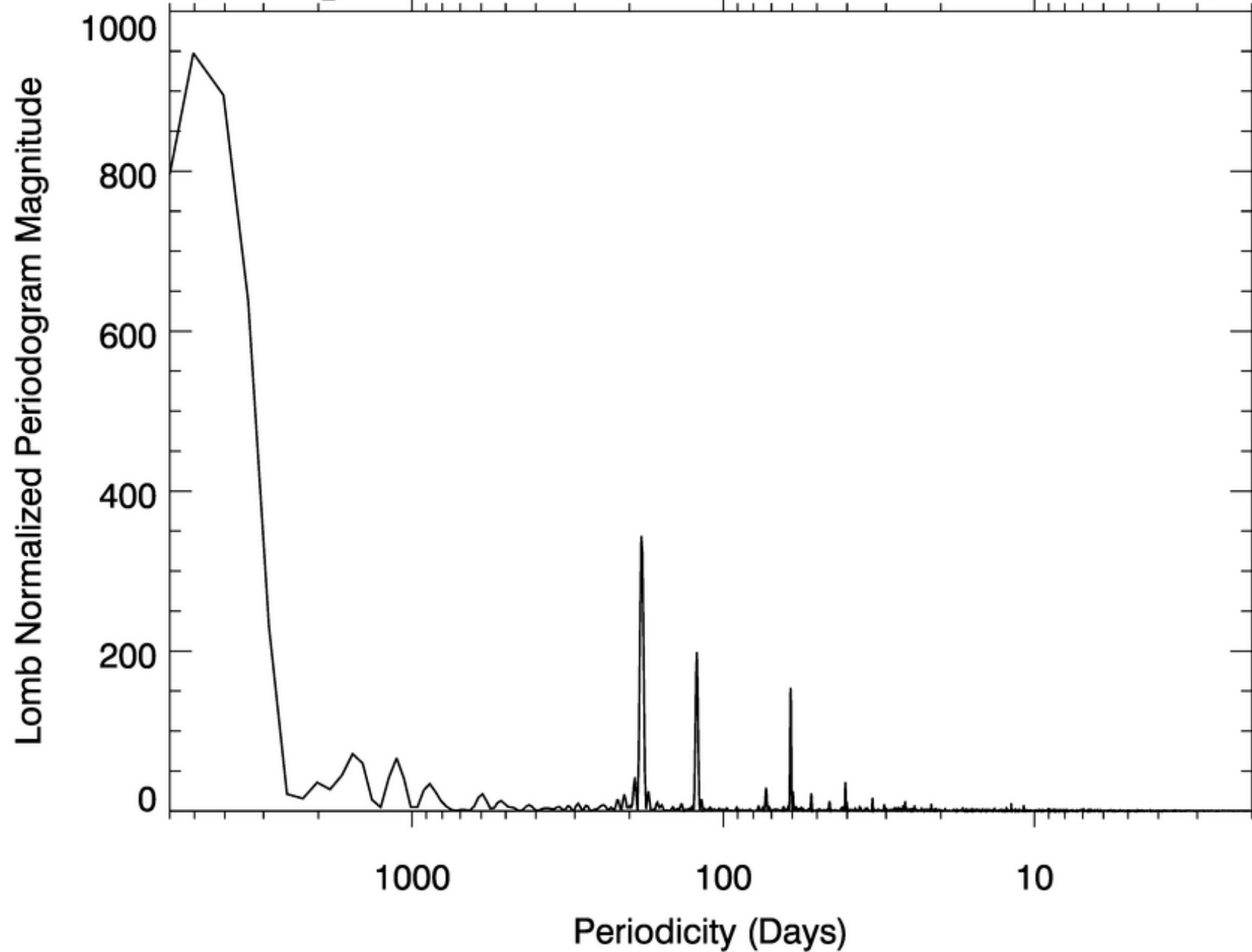


CO₂ Infrared Flux, Prior to and During the Halloween Storms, 2003

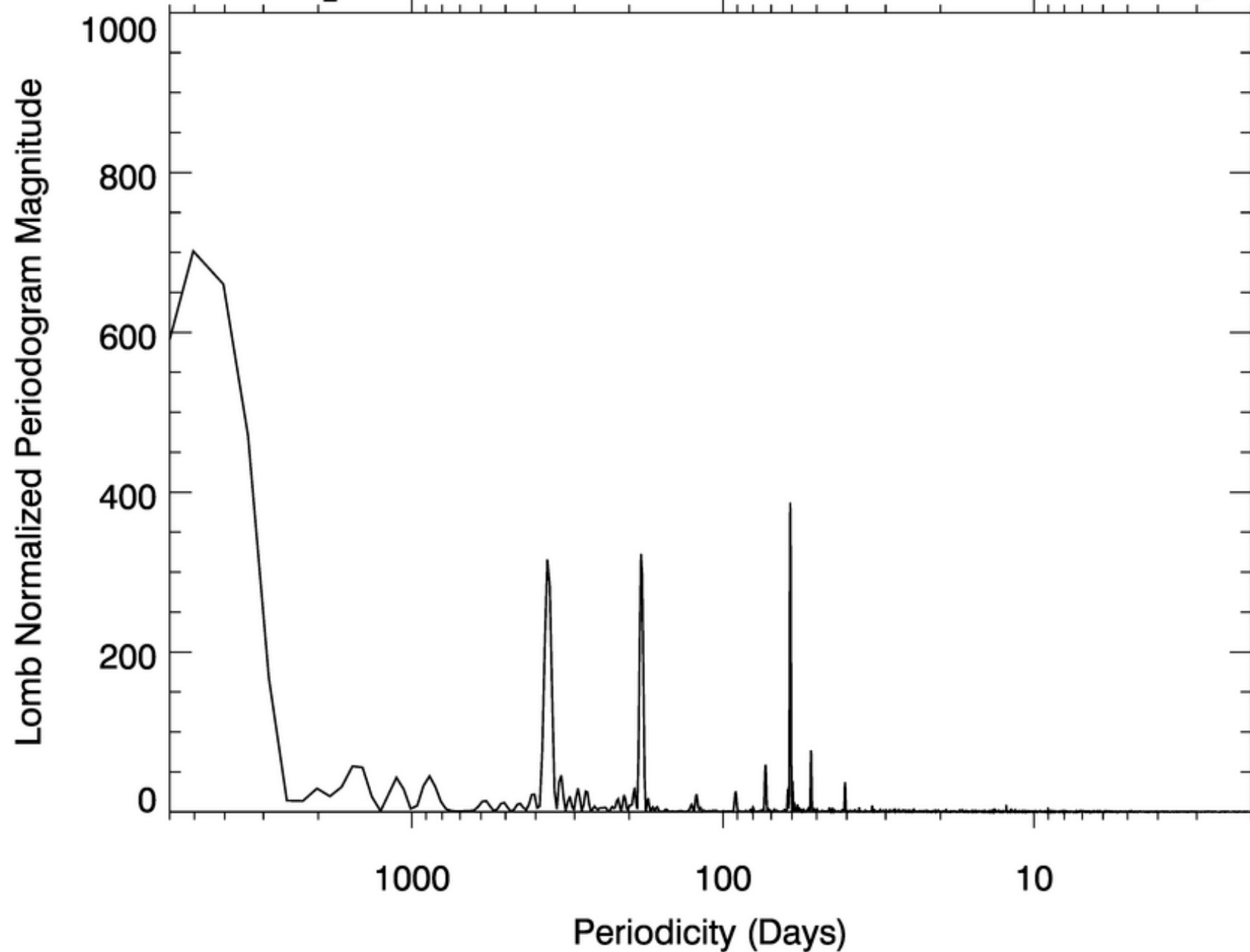
NO Flux, 10/21/2003 - 10/25/2003



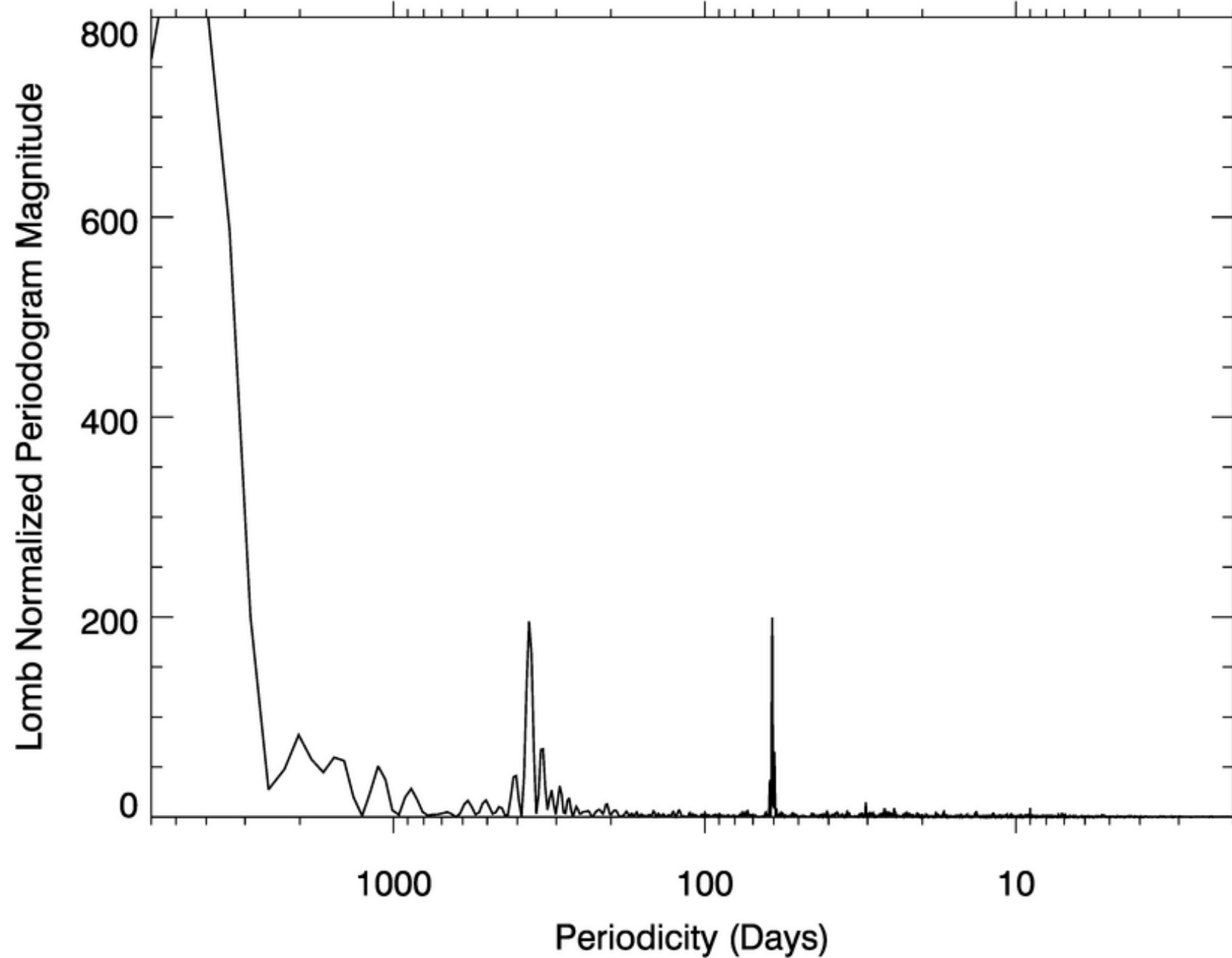
Global CO₂ Power 100-139 km 2002-2015 NH 0-55 Degrees



Global CO₂ Power 100-139 km 2002-2015 SH 0-55 Degrees



Global NO Power Power 100-250 km 2002-2015 SH 0-55 Degree



Global NO Power Power 100-250 km 2002-2015 NH 0-55 Degree

